SUBSURFACE GEOLOGY OF GEARY AND MORRIS COUNTIES, KANSAS

by

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INTRODUCTION

Geography

Location. Geary and Morris Counties are in northeastern Kansas, and have areas of 407 and 707 square miles, respectively.

Geary County is included within ranges 5, 6, 7, 8, and 9 east, and townships 10, 11, 12, and 13, south. The county is irregular in shape and is bounded by Riley and Wabaunsee Counties on the north and east, by Morris and Dickinson Counties on the south, and by Dickinson and Clay Counties on the west.

Morris County is included within ranges 5, 6, 7, 8, and 9 east, and townships 14, 15, 16, and 17 south. The county is irregular in shape and is bounded by Geary and Wabaunsee Counties on the north, by Wabaunsee and Lyon Counties on the east, by Marion and Chase Counties on the south, and on the west by Dickinson and Marion Counties.

The county seats of Geary and Morris Counties are Junction City and Council Grove, respectively.

Figure 1 illustrates the two counties investigated.

Physiography. Geary and Morris Counties lie within the Osage Plains section of the Central Lowlands physiographic province.

Sedimentary rocks dipping gently northwestward have been beveled by an eastward sloping erosional plain, and resistant north-south trending Permian strata form east to southeastward-

facing escarpments, some of which have been dissected into a range of hills known as the Flint Hills.

The average relief of Geary and Morris Counties is 500 and 400 feet, respectively, the average elevation being about 1300 feet for both counties.

Drainage. The confluence of the Republican River and Smoky Hill River at Junction City form the Kansas River. These rivers and their tributaries drain Geary County.

The Neosho River and its tributaries drain Morris County.

Previous Investigations

Surface Geology. The surface geology of Geary County has been described by Jewett (1941b) in a joint publication covering Riley and Geary Counties. Moore (1918), described the environment of Camp Funston, which is on the Fort Riley Military Reservation near Junction City. In 1896, Hay described the geology of the Fort Riley Military Reservation.

The surface geology and construction materials of Morris County have been described by Mudge. et al., (1958).

Sub-surface Geology. Several regional structural and stratigraphic studies include the area, or surrounding area, of this report. Lee, et al., (1948), and Lee (1956) have described the stratigraphy and structure of the Salina Basin (see fig. 6), and Lee (1943) has described the stratigraphy and structure of the Forest City Basin (see fig. 6). The Precambrian rocks have been described by Farquhar (1957), the

upper Cambrian and lower Ordovician rocks by Keroher (1948), the middle Ordovician limestones, the upper Ordovician rocks, and the Siluro-Devonian limestones by Taylor (1947a), (1947b), (1946), respectively. Lee (1940) described the Mississippian rocks, Jewett (1941a), (1945) classified and described the Marmaton group, and Moore (1949) described the rocks of the Pennsylvanian system.

The history of development of the oil and gas resources of the area are contained within reports by Folger (1933), Goebel, et al., (1956), (1959), (1960), by Jewett and Abernathy (1945), and by Jewett (1949), (1954).

Lee and Merriam (1954) constructed a series of cross sections in eastern Kansas, one of which extends through the panhandle of northwestern Geary County.

Regional geologic structural contour maps depicting the surface configuration of the Lansing group, "Hunton" group, and Mississippian rocks have been constructed by Merriam, et al., (1958), (1960), and by Merriam (1960d).

In 1959 Agocs reported on airborne magnetometer studies in Morris and Wabaunsee Counties.

Articles describing the Alta Vista (Merriam, 1960a), Burdick (Merriam, 1960b), Comisky (Hilpman, 1960a), Comisky Northeast (Hilpman, 1960b), John Creek (anon., 1960), Three Mile Creek and Three Mile Creek South (Kelley, 1960), and the Wilsey and Wilde (Smith, 1960) oil and gas fields of Morris County are contained within a Kansas Geological Society

publication describing the oil and gas fields of northeast Kansas.

A Kansas Geological Survey petroleum hotspot report by Hilpman and Goebel (1960) constitutes the published literature soley concerning the subsurface geology of Geary County.

Purpose of this Investigation

The purpose of this investigation is to analyze and describe the subsurface stratigraphic and structural conditions in Geary and Morris Counties, and to relate these findings to the accumulation of petroleum.

Generally speaking, relatively minor amounts of petroleum have been produced in northeastern Kansas as compared with the rest of Kansas. Geary and Morris Counties were chosen as the area for this investigation because of recent exploration and drilling activities in the area, and it is believed that this area has an excellent petroleum potential. It is hoped that this report will provide information which will aid in the discovery of new petroleum reserves.

Geologic conditions within the area are complicated by the presence of parts of 3 major regional structural features, the Nemaha Anticline, and the Forest City and Salina Basins.

Investigation Procedure

Information for this investigation was obtained by reviewing the available published literature, examination of

electric, sample and drillers logs at the library of the Kansas Geological Survey in Lawrence, and examination of well cuttings at the State Well Sample Library in Wichita.

Information from the Herndon Map Service was used to obtain locations of wells and depths to desired datums. This information was checked by examining "top cards" at the library of the Kansas Geological Survey, and where significant discrepancies existed between the two sources of information the data most closely fitting the existing conditions was used.

Structure contour maps were constructed depicting the surface configuration of 2 petroleum reservoirs in the area, the "Hunton" and Mississippian limestones.

An east-west stratigraphic cross section was constructed through Morris County using electric logs to "pick" the formation tops. A general stratigraphic column as depicted by an electric log was also constructed.

Additional figures have been included to clarify the data presented.

HISTORY OF OIL AND GAS DEVELOPMENT

Geary County

The earliest recorded drilling in Geary County was in 1904 by the Junction City Mining and Drilling Company. Two dry test wells located approximately 300 feet apart were drilled in sec. 16, T. 12 S., R. 5E. (Jewett, 1949). Within the next 48

years the Kansas Geological Survey records indicate only additional 16 test wells drilled (Jewett, 1954).

The first recorded commercial oil well, the Adair Oil Company's No. 1 Green well, opened the Ge-See field in October of 1959 in sec. 27, T. 11 S., R. 8 E. with production from a Cherokee sandstone at a depth of 1,749 - 1,761 feet (Goebel, et al., 1960). The Ge-See field extends into Riley County, and is approximately 2 miles southwest of the Yaege field of southeastern Riley County.

A second area, the Wingfield field, was opened in December, 1959 by the Jones - Gerbert Oil Company's No. 2 Scott well in sec. 35, T. 11 S., R. 8 E.. Mississippian oil was found at a depth of 1800 feet (Hilpman, et al., 1960). The Kansas Corporation Commission production report for December 31, 1960 did not list production figures for the Wingfield, and it is assumed that production was too small to be recorded.

Discoveries of the Ge-See, Wingfield, and the nearby Yaege fields substantially accelerated exploration and drilling activities in Geary County. It is anticipated that with increased activity more production areas will be opened.

Commercial gas production has not been reported in Geary County.

Figure 2 illustrates the location of the Geary County oil fields.

Table 1 lists general information pertaining to the Geary County oil fields.

Morris County

Gas was discovered in the 1920's and early 1930's in local anticlinal "highs" along the crest of the Nemaha Anticline. These are the Alta Vista, Heigle (pool) (later changed to Wilsey), Diamond Springs, Wilde, and Wilde N. W. (?) gas fields.

The Nelson field, Morris County's first oil field, was drilled in March of 1928 by the Gilliland Oil Company in sec. 30, T. 17 S., R. 5 E.. Production of oil from the Mississippian "chat" at a depth of 2,295 feet was reported (Jewett, 1949). In 1959 the Kansas Corporation Committee listed the Nelson field as being part of the Lost Springs field of Marion County.

Between 1932 and June, 1961 10 additional oil fields were developed. Listed in chronological order of development these are; the Burdick, Three Mile Creek S., Three Mile Creek, Nelson West (later combined with Lost Springs), John Creek, Veal, Comiskey, Comiskey N. E., Youtsey, and the Latimer.

Only three fields, Comiskey, Comiskey N. E., and the John Creek, are in the Forest City Basin east of the Nemaha Anticline.

The John Creek field, which in 1959 accounted for almost 75 percent of Morris County's production, was opened in December of 1953 by Wm. Gruenerwald's No. 1 Williams well in sec. 26, T. 15 S., R. 9 E.. Production of Viola oil at an average depth of 3,050 feet was reported from a structural high on the Alma Anticline. In September of 1960 the Gulf Oil Corp. unsuccessfully attempted to extend the Alma Anticline southward

in Morris County with their No. 1 Barth well in sec. 21, T. 16 S., R. 9 E., (Merriam, 1960).

Figure 2 depicts the oil and gas fields of Morris County.

Table 1 lists general information pertaining to the oil and gas fields of Morris County.

STRATIGRAPHY

General Statement

The stratigraphic sequence in the area ranges from Precambrian to Quarternary, and is represented graphically in figure 7. The thickness of the sedimentary cover overlying the Precambrian ranges from a maximum of approximately 3,400 feet in the Forest City Basin to a minimum of approximately 2,000 feet over the crest of the Nemaha Anticline.

The electric log of the Carter Oil Company's No. 1 Hale White well (sec. 17, T. 16 S., R. 8 E.) has been used to illustrate the generalized stratigraphic sequence from the base of the Simpson group to the middle of the Chase group. The generalized sequence from the Precambrian up to the base of the Simpson group has been represented by the electric log of the Lincoln Oil Company's No. 1 Breckbill well (sec. 24, T. 16 S., R. 5 E.). The generalized sequence from the middle of the Chase group to the Wellington limestone formation is represented diagrammatically, and has been adapted from Mudge, et al., (1958).

Well cuttings from the above mentioned intervals of the Hale White and Breckbill wells were examined to obtain lithologic descriptions of the formations present. Samples of the stratigraphic sequence from the top of the Bader limestone (Council Grove group) were not available, and descriptions of this sequence have been adapted from Jewett (1941b) and Mudge, et al., (1958).

Reference should be made to figures 3 through 7 while reading this material.

Precambrian Sequence

Precambrian rocks in the area have been penetrated by 18 wells, 13 in Morris County and 5 in Geary County.

Rocks belonging to the Precambrian sequence may be divided into two zones; an upper weathered zone commonly referred to as "granite wash", and a lower unweathered zone.

Unweathered Zone. Well cuttings from the Breckbill well contained quartz and fresh pink feldspar and biotite. Available reports from other wells that penetrated the Precambrian indicate the presence of either quartz, or, pink feldspar and quartz. This immediately suggests the presence of either white or pink granite. Well cuttings of a granite gneiss, however, would probably be difficult to distinguish from those of a granite.

Farquhar (1957) reports schist, gneiss, and quartizite cuttings in wells drilled to the Precambrian upon the Nemaha

Anticline and in the Brownville Syncline in nearby Pottawatomie County.

Weathered Zone. Samples of this zone were not available for examination. The material for the following discussion has been adapted from Farguhar (1957).

A layer of weathered granite commonly logged as "granite wash" generally overlies the unweathered Precambrian surface in Northeastern Kansas. This sediment is often loosely compacted, but not cemented, and is believed to be primarily residual, that is, formed by weathering in place of the granite. Its lithology would therefore be similar to the underlying unweathered material, however prolonged weathering would result in a sediment quite unlike the parent rock. Examination of cores revealed that the material in many cases retains the textural characteristics of the underlying unweathered zone, thus indicating weathering in-situ.

The presence of two types of weathered residual material have been noted; mechanically weathered material, for which the name weathered granite is reserved, and mechanically weathered and chemically decomposed material, for which the name "granite wash" is reserved.

The presence of decomposed feldspar and mica in well cuttings distinguish the "granite wash" from the underlying parent material. It would be difficult, however, to distinguish well cuttings of the weathered granite from those of the parent material. In the absence of cores, it is believed that only two

criteria could aid in determining the presence of the weathered granite: 1. an electric log indication of a porosity change, 2. a great decrease in drilling speed.

The Stanolind Oil and Gas Company's No. 1 Veal well (sec. 30, T. 17 S., R. 7 E.) logged 120 feet of "granite wash". This is an exceptional thickness, the average depth of the weathered zone is approximately 20-30 feet.

The weathering of the Precambrian surface occurred during the Precambrian-late Cambrian interval, and the top of the weathered zone is considered as representing the Precambrian surface.

Figure 4 is a map of the present configuration of the Precambrian surface.

Upper Cambrian System

Lamotte (Reagan) Sandstone. The Lamotte sandstone, a basal clastic Upper Cambrian deposit, rests non-conformably upon either the weathered or unweathered Precambrian surface, and is conformable with the overlying Bonneterre dolomite.

It consists of gray, coarse, rounded, and frosted sand-grains, and a minor amount of coarse, clear, subangular grains. The sand grains become slightly finer near the top of the formation, and the Lamotte sandstone appears to grade into the overlying Bonneterre dolomite.

Keroher (1948) reports the Lamotte sandstone as being occasionally arkosic at the base. This would make it difficult

to distinguish from the underlying Precambrian rocks, and undoubtedly some of the sandstone deposits have been erroneously called "granite wash".

Fourteen feet of the Lamotte sandstone was recorded in the Breckbill well.

Regionally, the Lamotte sandstone thins to the west from the Kansas-Missouri state border (Lee, 1956). It is therefore inferred that the 14 feet of Lamotte sandstone recorded in the Breckbill well, which is in the extreme western part of the area under consideration, represents a thickness somewhat slightly less than the average.

Bonneterre Dolomite. Although stratigraphically incorrect, the Bonneterre dolomite is commonly included with the overlying Arbuckle group. This procedure has not been followed in this report.

The Bonneterre dolomite conformably overlies the Lamotte sandstone and lies unconformably beneath the Roubidoux formation of lower Ordovician age.

The contact of the Bonneterre dolomite and the Roubidoux formation has been placed, perhaps too arbitrarily, at the top of a greenish shale, above which occurs a slight color change of the dolomite.

The Bonneterre dolomite consists of a gray, medium crystalline dolomite, and contains greenish shale beds near the top of the formation and sandy dolomite at the base. The formation contains a minor amount of chert, and is present throughout the entire area.

The electric log of the Breckbill well indicates the presence of 78 feet of Bonneterre sediments. It thins slightly towards the north, where part of it has been eroded from the crest of the rising Southeast Nebraska Arch.

Ordovician System

Arbuckle Group. Division of "Arbuckle" rocks in the Kansas subsurface was made possible by the work of McQueen (1931) who, using insoluble residues as a correlation criteria, traced the formations from their outcroppings in Missouri westward into the subsurface and up to the Kansas border.

The complete "Arbuckle" sequence, which ranges in age from upper Cambrian to lower Ordovician, is, in ascending order, the: Eminence dolomite, undifferentiated Gasconade and Van Buren formations, Roubidoux formation, and undifferentiated Cotter and Jefferson City dolomites. The lower two divisions, the Eminence and Gasconade-Van Buren sequence, are absent from the area of this report (Lee, 1943, 1956). An isopachous map of the Cotter-Jefferson City sequence (Keroher and Kirby, 1948) indicates that this division is absent from all of Geary County and that northern part of Morris County which is west of the axis of the Namaha Anticline. The complete sequence was most probably deposited over the entire area and subsequently removed from the crest of the rising Southeast Nebraska Arch by pre-Simpson erosion.

One hundred and fifty-six feet of "Arbuckle" rocks

consisting of tan and light gray, medium to coarsely crystalline dolomite, were recognized on the electric log of the Breckbill well. Chert is disseminated throughout the entire formation and becomes more profuse in the upper 32 feet. This upper cherty zone is tan in color and may possibly be the Cotter-Jefferson City dolomites. The sandy dolomitic zones which are characteristic of the Roubidoux formation were not observed to be present, thus making it difficult to define the contact of the Roubidoux and the Cotter-Jefferson City sequence.

The Arbuckle group thins northward and is thin over the crest of the Nemaha Anticline where it was partially removed by post-Mississippian erosion.

Within the Forest City and Salina Basins the "Arbuckle" is unconformably overlain by the Simpson group. Upon the crest of the Nemaha Anticline it locally lies in angular unconformity beneath the Cherokee group and the Fort Scott limestone of the Marmaton group.

Simpson Group. Middle Ordovician rocks lying stratigraphically above the Arbuckle group, and where the stratigraphic section is complete, beneath the Viola limestone, are classified as belonging to the Simpson group.

As a result of post-Mississippian erosion the Simpson group lies in angular unconformity beneath Cherokee sediments along the crest of the Nemaha Anticline.

The Simpson group consists of an unnamed lower formation, the St. Peter sandstone (middle), and the Platteville formation

(upper). The St. Peter sandstone lies in unconformable contact beneath the Platteville formation.

Sample logs of wells present in the Forest City basin area indicate that the Decorah formation, lying above the St. Peter sandstone, is occupying the position of the Platteville formation. The term Decorah formation, is not generally used in Kansas and has not been used in this report.

The lithology of the Simpson group is quite variable, and it was not possible to separate the formations on the basis of the well cuttings alone.

The electric log of the Hale White well indicated a three fold division of the Simpson group. These divisions have been taken, perhaps too arbitrarily, as representing the formations comprising the Simpson group.

The lower unnamed formation consists of a very sandy shale, 23 feet of which were logged.

The St. Peter sandstone consists of poorly sorted, white, angular to rounded, clear and weathered quartz grains. The unit is 50 feet thick on the electric log.

The upper part of the Platteville formation consists of thinly interbedded gray and black shales with tan and brown limestones and dolomites. The lower part of the formation is logged as a dolomitic sandstone, and interbedded gray and red shales with brown dolomite. Quantitatively, the shale predominates over the limestone in the Forest City Basin, and vice versa in the Salina Basin. The unit is 38 feet thick on the

electric log.

The Simpson group thickens towards the north, or, towards the center of the North Kansas Basin. It ranges from a featheredge over the Nemaha Anticline to a reported (Hilpman and Goebel, 1960) 203 feet thick in a well in sec. 36, T. 13, S., R. 5 E.

Viola Limestone. Limestone and dolomite of middle Ordovician age lying unconformably above the Simpson group and, in a normal stratigraphic sequence, unconformably below the Maquoketa shale comprise the Viola limestone. Upon the crest of the Nemaha Anticline the Viola lies in angular unconformity beneath the Cherokee group.

Taylor (1947a) has classified the Viola limestones and dolomites of central Kansas into member zones numbered descendingly from one to six. An attempt to correlate any or all of Taylor's zones with those observed in the Hale White well was not feasible.

Three zones were noted to be present in the Hale White well; an upper tan, non-cherty dolomite zone, a middle brown, cherty dolomite zone, and a lower tan, non-cherty limestone zone. The zones are, in descending order, 41, 20, and 17 feet thick, respectively, and may correlate with zones 3, 4, and 5 of Taylor, however their equivalence is highly uncertain. The speckled chert indicative of Taylor's zone 4 was not observed to be present in the middle zone of the Hale White well.

The upper non-cherty member observed in the Hale White well

well is absent from wells in southwestern Morris County indicating a thining towards the west.

Maquoketa Shale. The upper Ordovician shales overlying the Viola limestone, and in a normal stratigraphic sequence, underlying the "Hunton" limestones, comprises the Maquoketa shale. Post-Mississippian erosion has locally partially removed the Maquoketa shale and the overlying Devonian and Mississippian rocks so that it (the Maquoketa) lies in angular unconformity below the middle Pennsylvanian Cherokee group.

The lithology of the Maquoketa shale is divisible into 2 zones: 1-a lower zone consisting predominantly of gray-green, dolomitic shale, and a dark gray shale at the base, and 2-an upper zone consisting of gray, finely crystalline, very shaly dolomite, interbedded with minor amounts of gray, dolomitic shale.

The formation ranges in thickness from a featheredge over the Nemaha Anticline to a consistent 60-90 feet in the basins to the east and west. Seventy-eight feet of Maquoketa were logged in the Hale White well.

Lower Silurian Middle Devonian Systems

The Hunton group, where present, overlies the Maquoketa shale, and where the Mississippian rocks have not been eroded, it unconformably underlies the Chattanooga shale. Hunton rocks are locally absent from the crest of the Nemaha Anticline, and on the flanks of the anticline it lies in angular unconformity

beneath the Cherokee group.

No attempt was made to determine the Silurian-Devonian boundary which occurs within the Hunton limestones. However, as the limestones are relatively thin or absent in the southern part of the area (especially in the Forest City Basin) it is probable that whatever "Hunton" is present is predominantly, if not entirely, Silurian in age. In the northern part of the area a more complete "Hunton" sequence is present, 400 feet having been reported (Hilpman and Goebel, 1960). An isopachous map of the "Hunton" interval (Taylor, 1946) shows an elongated belt of thick deposits trending slightly east of north entering southwestern Geary County from Dickinson County. This accounts for the exceptional "Hunton" thicknesses reported in that area.

Sixty-nine feet of tan and gray, finely crystalline dolomite was recorded in the Hale White well. Minor amounts of chert and some oolitic dolomite was present near the base of the unit.

The sample log of the Breckbill well (sec. 24, T. 16 S., R. 5 E.) records 142 feet of "Hunton" present. Three zones are observable in this well; a lower zone similar to the "Hunton" sequence described in the Hale White well, a middle zone of gray and tan, cherty, crystalline dolomite, and an upper zone of white, coarsely crystalline dolomite.

Devonian-Mississippian Systems

The shale sequence which, in a normal stratigraphic sequence, lies beneath the Mississippian limestones and above

the Hunton group comprises the Chattanooga shale.

In the area west of the Nemaha Anticline the Chattanooga shale where present, is unconformably overlain by the Gilmore City and possibly the upper part of the Sedalia formations of upper Kinderhookian age. In the Forest City Basin, the Chattanooga shale is unconformably overlain by the Chouteau limestone of lower Kinderhookian age (Lee, 1956). On the flanks of the Nemaha Anticline the Chattanooga shale lies in angular unconformity below the Cherokee group. Wherever present the shale sequence is underlain unconformably by the Hunton group.

The terms Kinderhook and Chattanooga shale are often used interchangeably in the literature. As the shale sequence is in part (perhaps wholly) Devonian in age, the term, Kinderhookian shales, should be discarded.

The Meisner sandstone member at the base of the Chattanooga shale is of erratic distribution within the area, its thickness ranging from a featheredge to 5 feet. It is a gray, poorly sorted sandstone.

The Chattanooga shale may be divided into two lithologically dissimilar zones; an upper zone consisting of a gray-green silky shale, slightly dolomitic towards the top, and a lower zone of gray, platy shale. The lower zone can usually be "picked" on the gamma ray curve of the radioactive log as it is more highly organic than the upper zone and causes a stronger "kick". This lower zone may represent the Devonian section of the

Chattanooga shale, however this is highly speculative.

The thickness of the Chattanooga shale ranges from a featheredge on the flanks of structural "highs" to a maximum of 274 feet, which occurs adjacent to the east flank of the Nemaha Anticline.

Mississippian System

Where present, the Mississippian limestones unconformably overlie the Chattanooga shale, and lie in angular unconformity below the Cherokee group of middle Pennsylvanian age.

Separation of the Mississippian limestones in the subsurface is difficult and has not been attempted in this report. Information pertaining to the areal distribution of the limestones has been adapted from Lee (1943, 1956).

Mississippian formations present in the Salina Basin are, in ascending order; the upper member of the Sedalia dolomite, Gilmore City limestone, St. Joe limestone, Reeds Spring limestone, and undivided Burlington and Keokuk limestones. Initial movements of the Nemaha Anticline in early Kinderhookian post-Chattanooga time raised the area west of the Nemaha axis thus restricting the Kinderhookian post-Chattanoogan seas to eastern Kansas. The Chouteau limestone and upper member of the Sedalia dolomite is therefore absent from the Salina Basin.

A similar sequence is present in the Forest City Basin; the Chouteau limestone, and entire Sedalia sequence is present below the Gilmore City; and the Warsaw and Spergen limestones

are present above the Keokuk limestone.

Deposits of Mississippian "chat" are much more extensive in the Salina Basin than the Forest City Basin. The sparsely cherty Spergen limestone and younger formations provided little material for the formation of the "chat" in the Forest City basin (Lee, 1956).

Mississippian limestone deposits are absent from the crest of the Nemaha Anticline as the result of erosion when the region was peneplained during post-Mississippian time. They attain a maximum thickness in southeastern Morris County where 384 feet are reported.

Mississippian limestones consist of tan and gray, cherty and non cherty, crystalline to sucrosic limestone and dolomite deposits.

Pennsylvanian System

Pennsylvanian rocks in Kansas can be divided into three stages which are, in ascending order, Desmoinesian, Missourian, and Virgilian.

Desmoinesian Stage. The Desmoinian stage consists of two groups which are the Cherokee (lower), and the Marmaton (upper).

Cherokee Group. A sequence consisting predominantly of various types of sandstone and shale deposits lying essentially conformable beneath the Fort Scott limestone of the Marmaton group and unconformably above Mississippian through "Arbuckle" rocks constitutes the Cherokee group. Locally, over the crest

of the Nemaha Anticline "Cherokee" rocks are absent, having been removed during pre-Marmaton erosion.

Early "Cherokee" seas were restricted to the Forest City Basin as the result of early Pennsylvanian deformation which raised the area to the west of the Nemaha Anticline (Lee, 1956). Early "Cherokee" deposits are therefore absent from the Salina Basin area, and the "Cherokee" sequence is thickest in the Forest City Basin.

The "Cherokee" ranges in thickness from a featheredge on the flanks of the Nemaha Anticline to a reported 390 feet in southeastern Morris County.

The Hale White well contained 260 feet of various types of sandstone and shale, and minor amounts of limestone.

Marmaton Group. Over the crest of the Nemaha Anticline where the "Cherokee" is locally absent, the base of the Marmaton group lies in unconformably contact above lower Ordovician "Arbuckle" rocks.

The Marmaton group consists of alternating tan and gray limestones and gray-green and lignitic shale beds. Minor amounts of sandstone are present. With the exception of the Fort Scott limestone, it was not possible to differentiate the Marmaton group into formations.

The Fort Scott limestone is a tan and gray, dense limestone, contains a middle lignitic shale member, and is consistently between 15 and 22 feet thick. It can be "picked" from the electric log fairly easily, thereby facilitating the separation

the separation of the Marmaton and Cherokee groups.

The Marmaton group attains a maximum thickness of 150 feet east of the Nemaha Anticline, is approximately 90 feet thick on the crest of the anticline and thickens to approximately 110 feet west of the Nemaha Anticline. The entire sequence thickens slightly towards the north.

Missourian Stage. The Missourian stage unconformably overlies the Desmoinian stage and is divided into four groups which are, in ascending order: the Pleasanton, Kansas City, Lansing, and Pedee.

Pleasanton Group. A sequence predominantly consisting of sandstone and shale extending from the base of the Kansas City group to the top of the Marmaton group constitutes the Pleasanton group.

The thickness of the Pleasanton group ranges from a maximum of 94 feet east of the Nemaha Anticline to 25 feet or less on the crest of the anticline. It thickens westward from the anticline into the Salina Basin.

The thinning of the Pleasanton group over the Nemaha Anticline may be indicative of renewed uplift of the anticline during post-Marmaton pre-Kansas City time.

The Pleasanton group consists predominantly of gray-green, occasionally sandy or calcareous shales and minor amount of sandstone and limestone.

Kansas City Group. A sequence of thick limestone and thin shale beds extending from the top of the Pleasanton group

to the base of the Lansing group constitutes the Kansas City group.

The Kansas City group consists of six pairs of alternating limestone and shale formations. Some of the limestone formations include distinct shale members.

In their surface outcrops the formations are reported (Lee, 1956) to be fairly distinctive. Microscopic examination of the well cuttings, however, did not prove to be a suitable method of separation of the group into formations as many of the limestone beds are lithologically similar.

The electric log of the Hale White well revealed 295 feet of the Kansas City group to be present, and its thickness in the area ranges from 170-300 feet. The formations of the group are, in ascending order, the Hertha limestone, Ladore shale, Swope limestone, Galesburg shale, Dennis limestone, Cherryvale shale, Drum limestone, Chanute shale, Iola limestone, Lane shale, Wyandotte limestone, and Bonner Springs shale.

The Hertha limestone ranges from 10 to 20 feet in thickness, and is a white and gray, slightly fossiliferous, chalky limestone.

It can easily be "picked" on the electric log and thus provides a convenient datum for determining the base of the Kansas City group.

The Ladore shale is consistantly 4 to 5 feet thick, and is a black to gray-green shale.

The Swope limestone is a tan to white, sucrosic limestone, and it is commonly 13 to 18 feet thick. Minor amounts of chert may sometimes be present.

The Galesburg shale is approximately 10 feet thick and is a gray-black shale.

The Dennis limestone grades into the overlying Cherryvale shale, and it is difficult to determine the exact line of contact. The contact was placed at the top of the uppermost cherty limestone bed.

The Dennis limestone is a tan to white, flaky limestone which becomes cherty towards the top of the formation, and averages 30 feet in thickness.

The Cherryvale shale consists of gray-green, black, and brown shales which are sometimes calcareous, and averages 25 feet in thickness.

The Drum limestone is about 10 to 15 feet thick in the area and is a tan and white, chalky to flaky, cherty limestone.

The Chanute shale is a gray and green shale, and averages 10 feet in thickness.

The Iola limestone is a tan to white, very finely crystalline limestone which ranges from 12 to 22 feet in thickness.

The Lane shale ranges from 5 to 10 feet in thickness, and is a gray or gray-green shale.

The Wyandotte limestone is a tan to gray, very finely crystalline limestone which becomes cherty towards the top.

It ranges in thickness from 80 to 110 feet, and because of its thickness is a good electric log "marker".

The Bonner Springs shale is a gray, sandy shale, which in parts becomes a gray, very shaly, micaceous, sandstone. It ranges in thickness from 12 to 25 feet.

Lansing Group. A sequence of thick limestone and thinly interbedded shale beds lying above the Kansas City group and below the Pedee group where present, or disconformably below the Douglas group, constitutes the Lansing group.

Well cuttings of the limestone beds are lithologically similar, and the electric log was used to determine the positions of the formation contacts.

The thickness of the Lansing group in the area is fairly consistent, ranging from 80 to 110 feet.

The formations comprising the group are, in ascending order, the Plattsburg limestone, Vilas shale, and the Stanton limestone. The limestone formations contain one or more shale members.

The Plattsburg limestone is a tan, flaky limestone with minor amounts of chert present near the top of the formation. A thin, gray shale bed which is probably the Hickory Creek shale member is persistently present near the base of the formation.

The thickness of the Plattsburg limestone in the area ranges between 20 and 30 feet.

The Vilas shale is fairly thin in the area, ranging from 3 to 6 feet in thickness, and is a black, occasionally pyritic, shale.

The Stanton limestone ranges consistently between 40 and 50 feet in thickness, and consists of three limestone and two shale members.

The limestone beds are sucrosic, chalky, very finely crystalline, and are tan and gray in color. In some wells the upper part of the Stanton formation contains beds of dolomite.

Pedee Group. Forty-five feet of dark gray, platy shale lying above the Stanton formation and below the Tonganoxie sandstone member of the Douglas group was observed in well samples of the Hale White well. This shale sequence has been designated as the Pedee group.

Lee (1956) stated that the Pedee group is absent from the Salina Basin having been removed by post-Lansing pre-Douglas erosion. Electric logs throughout the area have been examined for the presence of the Pedee group. If present, it was not possible to separate it from the overlying Douglass group.

The Pedee group is overlain disconformably by rocks of the Virgilian stage.

Virgilian stage. The Virgilian stage is divided into 3 groups which are, in ascending order: Douglas, Shawnee, and Waubunsee.

Douglas Group. A sandstone and shale sequence unconformably overlying the Pedee group, or the Lansing group where

the Pedee group is absent, and underlying the Shawnee group constitutes the Douglas group.

Two formations, the Stranger formation (lower) and the Lawrence shale (upper) comprise the Douglas group.

The Stranger formation in the Hale White well was found to contain 3 divisions: the Tonganoxie sandstone (lower), Haskell limestone (middle), and a 40 foot shale sequence (upper) referred to in this report as the Robbins shale.

The Tonganoxie sandstone member has been studied by Lins (1950) who found it to contain 4 types of deposits, 2 of which have been recognized in the Hale White well: an upper gray and red shaly zone 10 feet thick, and a lower zone of interbedded sandy shale and very fine grained, micaceous, calcareous sandstone 30 feet in thickness. In the area west of the Nemaha Anticline the Tonganoxie sandstone was not distinguishable on the electric logs.

The Haskell limestone, a gray, oolitic, very dense limestone, averages 5 feet in thickness.

Locally, the Haskell limestone is overlain by a 20-40 foot chick, dark gray, platy shale sequence, occupying the stratigraphic position of the Robbins shale. The Robbins shale is not generally recognized north of Woodson County (Moore, 1951), however, it is believed that this shale sequence is the Robbins shale.

The Lawrence shale, with the exception of the Amazonia limestone and Ireland sandstone members, is not subdivided.

The Amazonia limestone, a gray to tan, slightly sandy limestone, lies consistently 25 to 30 feet below the top of the Lawrence shale, and has an average thickness of 8 feet.

The base of the Lawrence shale has been placed at the base of the Ireland sandstone where it overlies either the Haskell limestone or a shale sequence (Robbins shale?) which locally overlies the Haskell.

The Ireland sandstone member varies from a gray, sandy shale to a gray, shaly, sandstone, and averages 40 feet in thickness. A gray shale sequence commonly lies between the Ireland and the overlying Amazonia.

In Marion County the Ireland sandstone comprises the greater part of the Stranger formation (Lee, 1956), and although it has not been verified, it is believed that similar conditions may exist in the western part of the area under consideration.

Shawnee Group. The Shawnee group consists of 4 limestone formations which alternate with 3 shale formations. The limestones are tan, very dense, may or may not be fossiliferous, and commonly contain many shale members. The shale formations are characteristically sandy, gray in color, and frequently micaceous.

The formations of the Shawnee group listed in ascending order are: the Oread limestone, Kanwaka shale, Lecompton limestone, Tecumseh shale, Deer Creek limestone, Calhoun shale, and Topeka limestone. The entire sequence, including the members of the limestone formations can usually be identified

on the electric log.

The Heebner shale member of the Oread limestone contains an abundance of organic material and can easily be "picked" on the gamma ray curve of the radioactive log because of the strong "kick". This facilitates the separation of the Shawnee group from the underlying Douglas group.

The Shawnee group averages 300 feet in thickness.

Wabaunsee Group. The Wabaunsee group consists of an alternating sequence of limestone and shale formations lying above the Topeka limestone and unconformably below the basal Permian Onage shale formation.

It is difficult to accurately determine the Pennsylvanian-Permian contact in the subsurface, as the upper most Pennsylvanian and lower most Permian rocks both consist of an alternating limestone and shaly sandstone sequence.

The percentage of limestone present is slight relative to the amount of shale present, and cyclic repetition of limestone and shale members which comprise the formations precludes their accurate identification in the subsurface.

With the exception of the basal Severy shale formation, the Howard limestone and the Happy Hollow limestone member of the Scranton formation, the Wabaunsee formation is undifferentiated.

Permian System

Permian rocks in the area are sub-divided into two stages, Wolfcampian (lower) and Leonardian (upper).

Wolfcampian Stage. The Wolfcampian stage is divided into the Admire group (lower), the Council Grove group (middle), and the Chase group (upper).

Admire group. The Admire group averages 140 feet in thickness, consists predominantly of shale and sandstone, and extends from the base of the Indian Cave sandstone to the base of the Americus limestone of the overlying Council Grove group.

Two thick shale formations, the Onaga (lower) and the Jonesville (upper), separated by a thin limestone formation, the Falls City, form the subdivisions of the Admire group (Jewett, 1959). The shale formations are characteristically sandy and commonly contain one or more limestone members.

None of the subdivisions of the Admire group were recognized on the electric log, and the group is undifferentiated in this report.

Council Grove Group. A sequence of seven pairs of alternating limestone and shale formations extending from the base of the Foraker limestone to the base of the Wreford limestone of the overlying Chase group constitute the Council Grove group.

The formations were all recognized on the electric log and are listed in ascending order: Foraker limestone, Johnson shale, Red Eagle limestone, Roca shale, Grenola limestone, Eskridge shale, Beattie limestone, Stearns shale, Bader limestone, Easly Creek shale, Crouse limestone, Blue Rapids shale, Funston limestone, and Speiser shale.

The shale formations are characteristically varicolored

and the limestone formations lack the cherty deposits which are characteristic of the overlying Chase group.

The Johnson shale is the lowest outcropping Permian formation in Morris County (Mudge, et al., 1958) and the Eskridge shale is the lowest outcropping formation in Geary County (Jewett, 1941).

The Council Grove group averages 300 feet in thickness throughout the area.

Chase Group. The Chase group consists of an alternating sequence of colored shales and thick flinty limestones (Jewett, 1941).

The subdivisions of the Chase group are, in ascending order: the Wreford limestone, Matfield shale, Barneston limestone, Doyle shale, Winfield limestone, Odell shale, and Nolans limestone. Only the three lower most formations were present on the electric log of the Hale White well.

The entire Chase group is exposed in Morris County, the average thickness is 300 feet (Mudge, et al., 1958), and probably averages 250 feet in Geary County. The Winfield limestone is the uppermost rock unit of this group present in Geary County (Jewett, 1941).

Leonardian Stage. The only subdivision of the Leonardian stage present in the area is the Sumner group.

The Sumner group is the uppermost Permian unit present in the area. An average of 30 feet of the Wellington formation, capped by the Hollenberg limestone member, crops out in the

southwestern part of Morris County (Mudge, et al., 1958).

Cretaceous and Quaternary Systems

Jewett (1941) mapped a sandy soil overlying the Fort Riley limestone member of the Barneston limestone formation in the vicinity of Junction City, and suggests that it may be residue from weathered Dakota sandstone of Cretaceous age.

Hay (1896) identified Cretaceous outcrops in the same vicinity, and Jewett (1941) suggested that the outcrop may have weathered to a sandy soil in the years since Hay's report.

Unconsolidated loss, alluvium, and terrace deposits are present throughout the area.

STRUCTURE

General Statement

Figures 5 and 6 indicate the pre-Mississippian and post-Mississippian regional structures, respectively. Figures 8 and 9 illustrate the configuration of the surfaces of the "Hunton" and Mississippian limestones, respectively.

An east-west cross section (figure 10) depicting the interval between the top of the Lansing and the Precambrian shows the structural conditions within the area, and figure 3 illustrates the pre-Pennsylvanian areal geology within the area. These figures should be referred to while reading the following section.

Regional

In order to achieve proper perspective relating to the subsurface areal geology (especially the pre-Pennsylvanian areal geology) and the conditions affecting petroleum accumulation it seems necessary to review the development of the regional structural units, or provinces. Areas have at various geologic times been uplifts, then basins, then uplifts again, and vice-versa.

Lee (1943), (1956) and Lee, et al., (1948) through the preparation of stratigraphic cross sections and isopachous maps distinguished five periods of regional deformations in the Forest City-Salina Basin area. They are, in ascending order of occurrence: pre-St. Peter deformation; post-St. Peter, pre-Chattanooga; early Mississippian through and including Permian; post-Permian, pre-Cretaceous; post-Cretaceous through the present time.

Pre-St. Peter Deformation. As evidenced by the lack of early and middle Cambrian strata in eastern Kansas, erosional processes must have been dominant during this time. The widespread distribution of the LaMotte (Reagan) sandstone and the Bonneterre dolomite indicates a relatively level Precambrian surface. The present configuration of the Precambrian surface is the result of the numerous stages of deformation which have affected the basement complex.

A thickness map of the Arbuckle group in northern Missouri and northeastern Kansas (Lee, 1956) indicates contemporaneous

subsidence and uplift in late Cambrian and early Ordovician time. This regional warping produced the northward trending Ozark Basin of Missouri, and a broad structural uplift in southeastern Nebraska that extended into northeast Kansas now known as the Southeast Nebraska Arch.

Uplift and erosion occurred prior to the deposition of Simpson sediments and the "Arbuckle" dolomites were beveled so that they thin in a northwesterly direction.

Post-St. Peter, Pre-Chattanooga Deformation. The most prominent structural features developed in eastern Kansas during this second period of deformation are the Chautauqua Arch and the North Kansas Basin.

The pre-Simpson Southeast Nebraska Arch underwent, during post-Simpson time, a long period of differential subsidence which resulted in the pre-Chattanooga North Kansas Basin which lies north of the Chautauqua Arch and east of the Ellis Arch. Extensive Siluro-Devonian seas in the basin deposited the "Hunton" group, which is absent from southeastern Kansas.

Uplift of the Ozark Basin of Missouri in post-St. Peter time resulted in the positive Ozark Uplift. A westward extension of the Ozark Uplift known as the Chautauqua Arch, is recognizable in the Kansas subsurface, as is the Ellis Arch, by a broad band of "Arbuckle" rocks surrounded by progressively younger Ordovician strata and overstepped by Chattanooga sediments (Jewett, 1954).

The Ozark Uplift, Chautauqua Arch, and Ellis Arch formed one broad continuous positive element, the Central Kansas Arch, which left the Devonian Transcontinental Arch at right angles and trended eastward (Eardly, 1951).

Pre-Chattanooga rocks dipping outward form the northwest flank of the Chautauqua Arch and are known in the Kansas subsurface as the Ozark Monocline. The Ozark Monocline may also be considered as the southeast flank of the North Kansas Basin (Jewett, 1954).

Early Mississippian-Late Permian Deformation. Studies by Lee (1943), (1956) and Lee, et al., (1948) indicate that two simultaneous types of deformation occurred during early Mississippian time.

A thickening towards the north of Mississippian sediments older than Osagian indicate a northward tilting of the region, or continued subsidence of the North Kansas Basin. A thickening to the south of Osagian and younger Mississippian sediments indicates a southward regional tilting after the end of Kinderhookian time.

The absence of Mississippian limestones and dolomites older than the upper member of the Sedalia dolomite in an area west of the Nemaha axis suggests that the area was raised from early to late Kinderhookian time (excluding Chattanooga time). These movements may have been initial suggestions of the Nemaha Anticline.

Differential folding and uplift in the area of the North

Kansas Basin at the end of Mississippian time resulted in the development of the Nemaha Anticline, and Forest City and Salina Basins. Lee (1956) suggested that erosion of the Mississippian and older sediments from the crest of the anticline kept pace with the emergence, and the structure was therefore never greatly above sea level. The Nehaha Anticline was again uplifted, folded and faulted along part of its east limb before the start of Pennsylvanian time. It remained emergent until perhaps middle Cherokee time, restricting the Cherokee sea to the Forest City Basin. This is evidenced by the distribution of Cherokee sediments within the Forest City and Salina Basins. A thick Cherokee section is present within the Forest City Basin and a relatively thinner section present in the Salina Basin. In both basins the Marmaton group conformably overlies the Cherokee group.

The Chautauqua Arch showed little signs of activity in Mississippian time.

The Central Kansas Uplift (Barton Arch) which developed, in part, in the area of the Central Kansas Arch, was mildly developed in pre-Mississippian time (Lee, 1956) and strongly rejuvenated at the close of Mississippian time. A core of Precambrian rocks surrounded by bands of progressively younger strata outline the uplift in the subsurface. The youngest formation missing from the area is the basal Hertha limestone of the Kansas City group (Lee, 1956).

In middle Pennsylvanian time the Forest City Basin was for a short period of time separated into two basins, the Forest City to the north and the Cherokee to the south. The northwest-southeast trending divide, known as the Bourbon Arch, is expressed by a thinning of Cherokee and Mississippian sediments (Jewett, 1954). The Cherokee basin occupies, in part, the location of the Chautauqua Arch.

The Salina Basin was at some time between post-Mississippian and pre-Kansas City time, divided into two basins, the Sedgwick to the south and the Forest City to the north. The low-unnamed divide trended roughly east-west, and according to Lee (1956), probably had no expression by the start of Kansas City time.

Structural movements of the major post-Mississippian structures continued throughout Pennsylvanian and Permian time, though with decreasing vigor, until cessation shortly after Barneston time (lower Permian).

Post-Permian, Pre-Cretaceous Deformation. Details of this deformation are obscure owing to the hiatus that exists between Permian and Cretaceous time. The effect of the post-Permian pre-Cretaceous movements was to give the region a gentle westward dip.

Post-Cretaceous Deformation. Deposition of Cretaceous sediments upon beveled Permian strata; regional tilting towards the north superposed upon the existing westerly dip (resulting in a regional northwesterly dip); and elevation of the Cretaceous and older strata approximately 2,000 feet to their

present altitude, are the main effects of the post-Cretaceous deformation.

Subsurface Structure of Geary and Morris Counties

The most prominent subsurface structural features of the area under consideration are sections of the post-Mississippian Nemaha Anticline, and Salina and Forest City Basins.

Lines delineating the areas where the Hunton and Mississippian limestones are absent in the subsurface outline the trend of the southwestward plunging Nemaha Anticline. The anticline trends southwestward through Morris County and is present only in the eastern portion of Geary County.

Lee (1943) describes, with some detail, the history of the term Nemaha Anticline. Briefly, previous concepts held that the structure was either a buried mountain system or a buried granitic ridge, and the time of deformation was dated as ranging between Precambrian and pre-Pennsylvanian time. The present and almost universally held concept states that the structure is a truncated, southwestward plunging, anticlinal fold, with a core of Precambrian granitic material that was essentially formed by post-Mississippian, pre-Des Moinesian deformation. The structure was never at any time more than 50 or 100 feet above sea level (Lee, 1956) thus the term Granite ridge which is still prevalent is a misnomer, and should be discarded.

The relative positions of the pre-Mississippian North

Kansas Basin and the post-Mississippian Nemaha Anticline, Forest City and Salina Basins is suggestive of the Nemaha Anticline having bisected the North Kansas Basin thus forming the post-Mississippian basins (compare figures 5 and 6). Lee (1956) states that "...neither the Salina nor the Forest City basin bears a close resemblence to the North Kansas Basin", and, that it seems probable that the Salina structural basin which lies between the almost contemporaneous Nemaha Anticline and Central Kansas uplift "...would have been formed even had there been no North Kansas basin."

Post-Mississippian uplift and erosion has resulted in the removal of older sediments off structural "highs" located along the crest of the Nemaha Anticline.

Articles by Lee (1954) and Merriam (1956) relating the relationship of earthquakes and subsurface structural features indicate that minor stress adjustments are still taking place, and that the Nemaha Anticline is still subject to perodic elevation.

The close spacing of the structure contour lines adjacent to the "zero lines" of the Mississippian and "Hunton" surfaces emphasizes the asymetrical shape of the Nemaha Anticline, and strongly suggests faulting of the east flank.

Faulting of the east flank of the Nemaha has been noted in Oklahoma and Nebraska, and in one part of Wabaunsee County the structural relief on the Precambrian surface is more than 1000 feet in less than a mile (Farquhar, 1957). The Alma Anticline,

an anticline formed contemporaneously with the Nemaha Anticline, is faulted on its east flank (Smith and Anders, 1951).

Lee (1956) constructed a cross section across northern Wabaunsee County using equal horizontal and vertical scales. This cross section indicates that a sudden increase of dip of the east flank occurs which amounts to not more than six or seven degrees. It is therefore not necessary to everywhere postulate faulting to account for the asymetry of the structure. Recent publications (i.e. Merriam, 1960d) have demarked the east limb as a zone of "steep dip", rather than a fulted zone, indicating his acceptance of Lee's proposal.

Within the area under consideration, the east flank has not, with the exception of a few scattered wells, been tested, and conclusive evidence of faulting does not exist.

The axis of Forest City Basin essentially parallels that of the Nemaha Anticline (Lee, 1956), and the east limb of the anticline and the west limb of the basin are common to both structures.

The southwest corner of the basin lies within the eastern part of Morris County and does not enter into Geary County. That section of the basin which lies in Morris County is the southern most part of the Brownville Syncline. The Brownville Syncline extends southward into Kansas from Nebraska, and is the deepest part of the Forest City Basin (Jewett, 1951).

As a separate depositional basin, the Forest City (and Salina) was relatively short lived. It was formed contemporaneously with the Nemaha Anticline and Salina Basin, and remained

separated from the Salina Basin until late Cherokee, early Marmaton time when Pennsylvanian seas deposited sediments across the crest of the Nemaha Anticline thus uniting the two sedimentary basins.

In the eastern part of Morris County the post-Mississippian beds exhibit the regional northwestward dip while the Mississippian and older rocks dip eastward. As the flank of Nemaha Anticline is approached the entire rock sequence present is affected by the structural relief of the anticline resulting in an eastward dip (see figure 10).

The axis of a minor post-Mississippian structure, the Alma Anticline, parallels that of the Nemaha Anticline and is east of it in the Brownville Syncline (Smith and Anders, 1951). It is strongly asymetrical and is faulted along its east limb, thus giving the appearance of a miniature Nemaha Anticline. The exact northern and sourthern limits of the anticline are not clearly defined. Its known limits extend from northeastern Morris County to southeastern Pottawatomie County. Exploratory drilling (sec. 21, T. 16 S., R. 9 E.) failed to extend the anticline southward (Merrian, 1960c). The anticline is not present in Geary County.

The John Creek Anticline, a structural "high" of the Alma Anticline, is in T. 15 S., R. 9 E.. The time of folding of the structure is assumed to be synonomous with that of the Davis Ranch Anticline, a structural "high" located along the Alma Anticline in Wabaunsee County. The age of folding of the Davis

Ranch Anticline occurred during post-Mississippian, pre-Cherokee time, as revealed by the thicknesses of the units older than the Mississippian, which remain essentially equal with increased depth (Smith and Anders, 1951).

The Salina Basin lies to the west of the Nemaha Anticline and the east flank of the basin and the west flank of the anticline are common to both structures. The basinal axis trends northwestward and is sub-parallel to the axis of the Central Kansas Uplift. The southeastern corner of the basin occupies approximately 50 percent of the area under consideration.

The sediments in the basin exhibit the regional westward dip, though they are steeply upturned near the flank of the Nemaha Anticline. The regional character of the dip is interrupted, locally, by anticlinal and synclinal flexures.

FACTORS AFFECTING PETROLEUM ACCUMULATION

Petroleum accumulation in the known areas of present or former accumulation as defined by drilling can be attributed primarily to structural traps. In a few fields the traps are strictly of a stratigraphic nature, and in one field accumulation in two zones is the result of combined structural and stratigraphic conditions.

In 1959, production of oil from the Viola limestone from the John Creek field accounted for almost 75 percent of Morris County's oil production (Merriam, 1960c). The trap is a faulted,

closed anticline on the Alma anticline. The fault does not appear to control the entrapment of the petroleum.

The Comiskey N. E. field is on an anticline en echelon to the Alma Anticline. The trap is structural (Hilpman, 1960) and it seems probable that it was formed by the post-Mississippian pre-Cherokee regional deformation that formed many of the northeast trending folds.

The Three Mile Creek and Three Mile Creek South fields are examples of stratigraphic traps. Petroleum accumulation results from updip permeability and porosity "pinchouts" of beveled Mississippian rocks on the regional dip (Hilpman, 1960).

Gas production in the area has been obtained from shallow anticlinal traps on the crest of the Nemaha Anticline. The structures are an expression of differential compaction over the saddles that formed upon the Precambrian surface during the deformations that occurred since Precambrian time.

The Ge-See and Wingfield fields are on two separate pre-Pennsylvanian broad anticlinal structures depicted on figure 8 in northeast Geary County.

AREAS FOR FUTURE EXPLORATION

The area under consideration has been incompletely tested for the presence of petroleum, and it is believed that this analysis indicates that numerous possibilities remain for future exploration. As of May 31, 1961, only 38 wells have been drilled in Geary County and 374 wells in Morris County, averaging

approximately 1 well drilled per 11 square miles, and 2 square miles, respectively. Nearly 60 percent of the wells in Morris County have been drilled within approximately 4 percent of the land area. By excluding these wells, the average for Morris County is lowered to approximately 1 well drilled per 4.5 per square miles, and it is believed that this figure more accurately indicates the concentration of wells drilled.

Uplift and weathering at the end of "Arbuckle", Viola, Hunton, and Mississippian time undoubtedly increased the porosity of these units. The possibility of additional stratigraphic traps resulting from an updip porosity and permeability "pinchout", of beveled Mississippian and pre-Mississippian strata therefore seems worthy of future investigation. The traps of the Three Mile and Three Mile Creek South fields are of such a nature, and thus provide evidence of their existance. Figure 3 illustrates the pre-Pennsylvanian areal geology, and it is believed that careful attention should be given to those areas where known reservoir rocks lie unconformably beneath Pennsylvanian rocks.

It is believed that the regional deformation which produced the Nemaha and Alma Anticlines may have resulted in the formation of other northeast trending anticlinal structures en echelon to these. An unsuccessful attempt to extend the Alma Anticline southward (Merriam, 1960c) does not provide conclusive proof of its nonexistance. Perhaps more diligent exploration will result in the extension of this structure or

the discovery of one en echelon to it. The structure of the Comiskey N. E. field is that of an en echelon anticlinal fold.

Accumulation has been found in the area, and elsewhere, in Pennsylvanian and lower Permian sandstones of local occurrence. Reservoirs of this type, however, cannot be detected from the surface by either geological or geophysical means, hence it is believed that they will be found only by random drilling.

The structure contour map of the "Hunton" surface (figure 8) indicates 2 broad southwestward trending anticlinal structures west of the Nemaha. No closure is indicated, but this may simply be the result of the large contour interval used (C.I.= 100 feet). A lack of control within the area precluded the use of a smaller interval.

The structure contour map on the surface of the Mississippian limestones (figure 9) similarly indicates 2 broad southwestward trending anticlinal structures which are lacking closure. Again, this may be the result of the large contour interval used (C.I.= 50 feet).

A closed anticline is indicated in T. 15 S., R. 5 E. (figure 9), and it is believed that at least 30 feet of closure would have been indicated had a smaller contour interval been used (i.e., 10 feet).

SUMMARY OF FINDINGS

The stratigraphic sequence in Geary and Morris Counties ranges from Precambrian to Quaternary. A normal sequence is

present in the basins to the east and west of the Nemaha Anticline, and on the flanks of the anticline Cherokee rocks overstep beveled Mississippian and progressively older sediments. Locally, "Cherokee" rocks are absent and rocks of the Marmaton group overlie eroded Arbuckle sediments.

The area has been subjected to five periods of regional warpings. The third period, which ranged from early Mississippian through Permian time, was strongest during post-Mississippian pre-Des Moinesian interval, and resulted in the formation of the Nemaha Anticline, Forest City and Salina Basins. Sections of these 3 major regional structures are present within the area.

The area of this report has been incompletely tested for the presence of petroleum. Wells drilled in Geary and Morris Counties average approximately 1 per 11 square miles and 4.5 square miles, respectively.

Petroleum accumulation in the known areas of present or former accumulation can be attributed primarily to structural traps.

Numerous possibilities for discovery of new petroleum reserves remain as yet untested within the area. It is believed that additional stratigraphic traps resulting from updip permeability and porosity "pinchouts" of beveled Mississippian and older rocks exist within the area, and that careful attention should be given to those areas where known reservoir rocks lie unconformably beneath Pennsylvanian sediments. The Alma Anticline may conceivably be extended

southward by more diligent exploration, or other en echelon folds may be discovered. Two broad, southwestward trending anticlines are present in the area, however, lack of control precluded the use of a contour interval small enough (i.e. 10 feet) to show any closures which may exist. A closed anticline is indicated in T. 15 S., R. 5 E. (figure 9), and it is believed that at least 30 feet of closure would have been indicated had a smaller contour interval been used (i.e. 10 feet).

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APPENDIX

Table 1. Oil and gas fields, Geary and Morris Counties, Kansas.

Field	Gas Oil	Discovery well	Location	Company	Date	Producing zone	Aver. depth	Prod.[1]
				Geary County				
Ge-See	O	No. 1 Green	27-11s-8e	Adair	10-59	Cherokee	1755	Yes
Wingfield	O	No. 2 Scott	35-11s-8e	Jones-Gerbert	12-59	Miss.	1800	No
				Morris County				
Alta Vista	G	No. 1 Jacobs	10-14s-8e	Rose	4-32	Indian Cave	500	No
Burdick	O	No. 1 Atkinson	15-17s-5e	Loomis	10-49	Miss.	2246	Yes
Comiskey	O	No. 1 Lee	23-16s-9e	Drolte & Kuper	12-55	Viola	2987	No
Comiskey NE	O	No. 1 Teel	24-16s-9e	Drolte & Kuper	3-56	Viola	2925	Yes
Diamond Springs	G	----------	? -17s-6e	----------No	I n f o r m a t i o n			----------
Heigle (pool)[2]	O	No. 1 Heigle	11-16s-7e	Gen. Utilities	5-28	Lansing	1440	No
						Admire	440	No
John Creek	O	No. 1 Williams	26-15s-9e	Gruenerwald	3-54	Viola	3050	Yes
Latimer (pool)	O	No. 1 Abeldt	14-15s-5e	Adair	11-59	Miss.	2168	No
Nelson[3]	O	?	30-17s-5e	Gilliland	3-28	Miss.	2295	? 3
Nelson West[3]	O	No. 1 Bura	30-17s-5e	Musgrove	9-53	Miss.		? 3
Three Mile Creek	O	No. 1 Burns	25-16s-5e	Koester & Mergen	6-50	Miss.	2220	Yes
Three Mile Creek S.	O	No. 1 Grass	35-16s-5e	Loriaux	10-50	Miss.	2195	No
Veal	G	No. 1 Veal	30-17s-7e	Stanolind	7-55	Indian Cave	1237	No
Wilde	G	No. 1 Wilde	15-17s-7e	Arrow	6-30	Ireland	1200	No
						Lansing	1400	No
						Willard ? or Indian Cave	600	No
Wilde NW	G	----------	N o I n f o r m a t i o n					
Wilsey[2]	G	No. 1 Hammer	14-16s-7e	Gen. Utilities	2-27	Admire	410	No
						Lansing	1425	No
Youtsey	O	No. 1 Youtsey	13-16s-5e	Sunflower	4-57	Miss.	2270	No

[1]Reported petroleum production as of December 31, 1960 (Kansas Corporation Committee report)

[2]Heigle pool later changed to Wilsey field

[3]Now part of Lost Springs field, Marion County

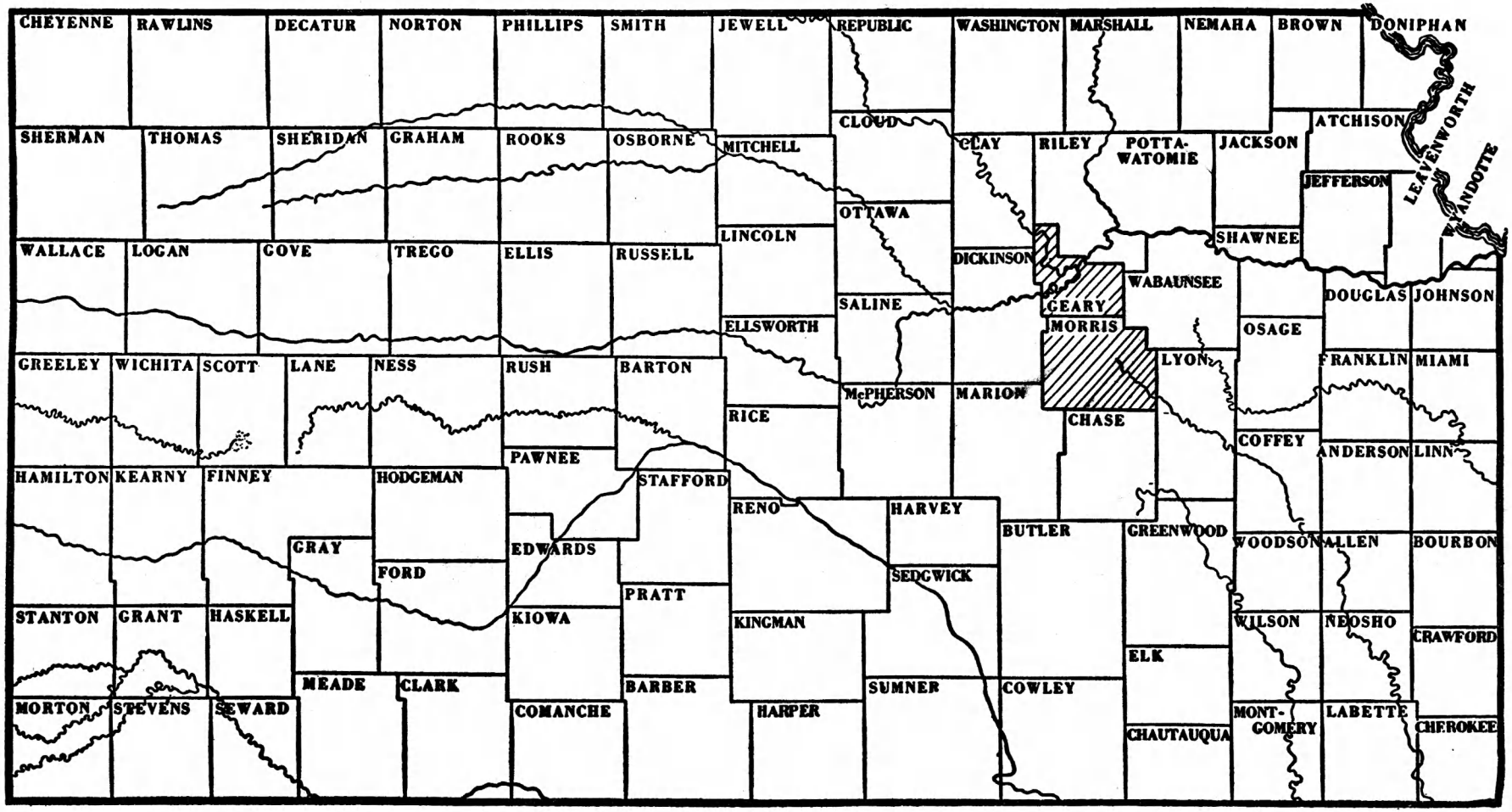


Fig. 1. Index map showing Geary and Morris Counties, Kansas.

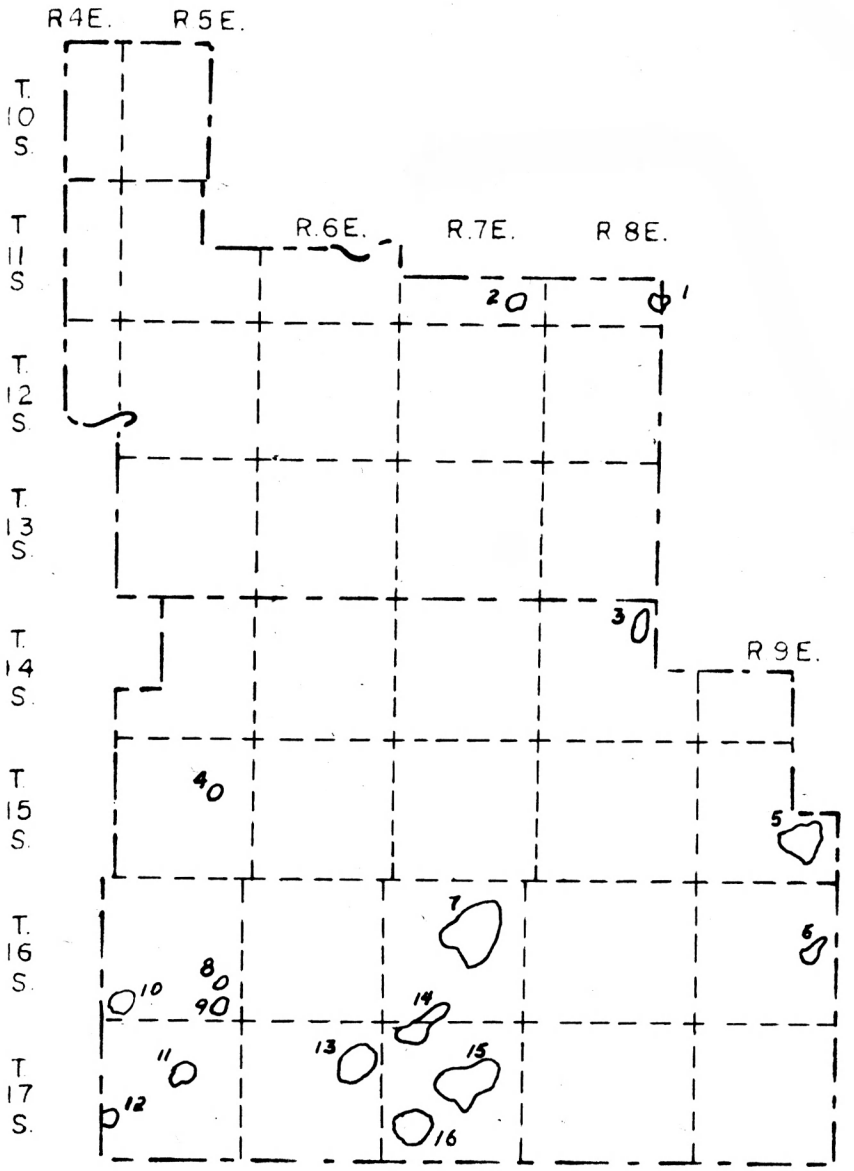


Fig. 2 Oil and gas fields, Geary and Morris Counties, Kansas

1. Ge-See
2. Wingfield
3 Alta Vista
4. Latimer
5. John Creek
6 Comiskey & Comiskey NE.
7. Wilsey (Heigle)
8. Three Mile Creek
9. Three Mile Creek S.
10. Youtsey
11. Burdick
12. Nelson & Nelson W.
13 Diamond Springs
14. Wilde NW.
15. Wilde
16. Veal

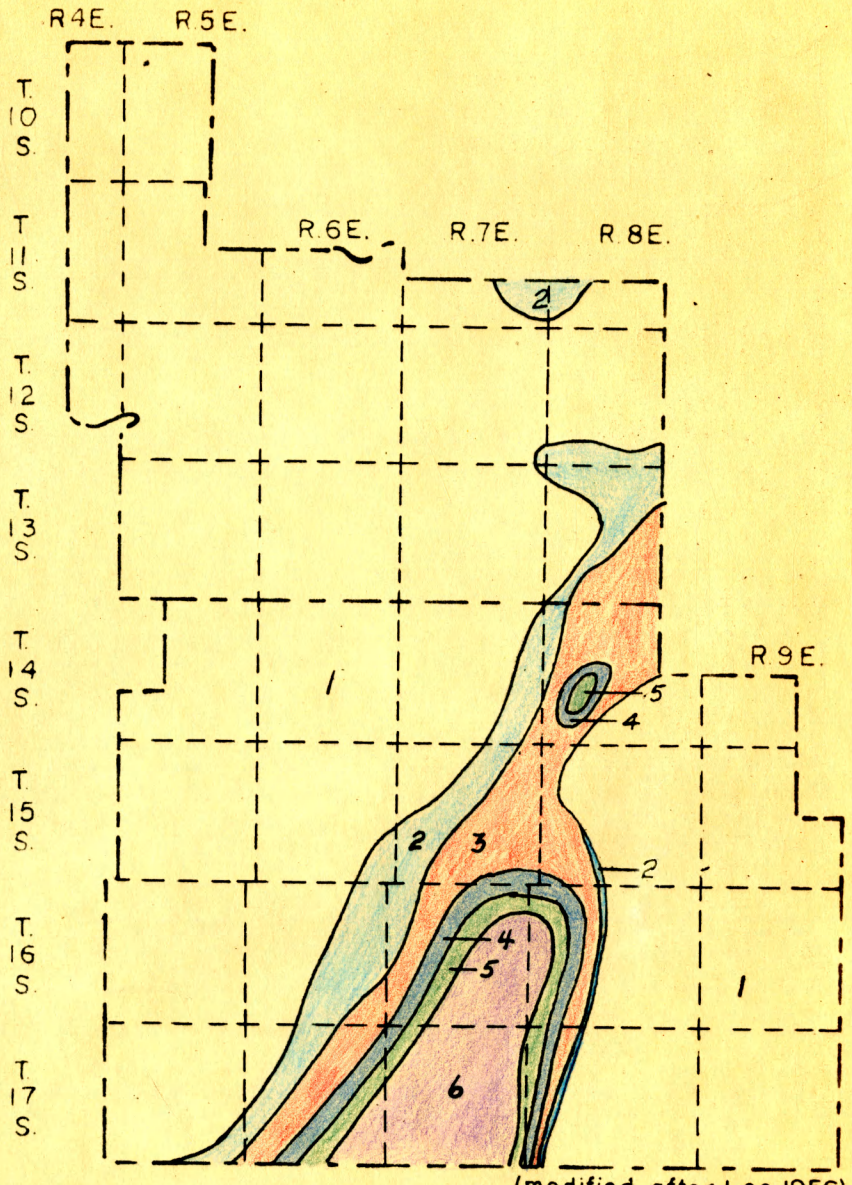


Fig. 3. Pre-Pennsylvanian areal geology, Geary and Morris Counties, Kansas.

1. Mississippian ls.
2. Chattanooga sh.
3. "Hunton" ls.
4. Maquoketa sh.
5. Viola ls.
6. "Arbuckle" ls.

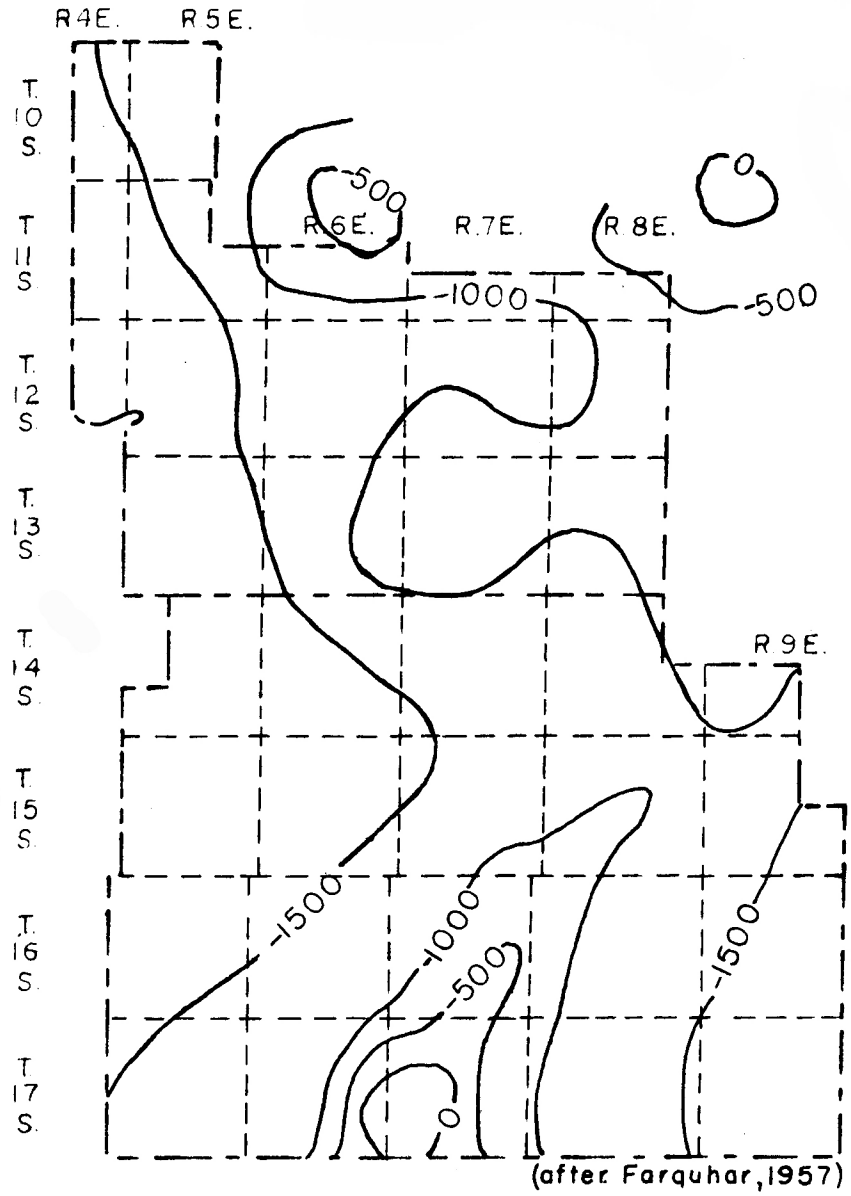


Fig. 4 Configuration of the Precambian surface, Geary and Morris Counties, Kansas

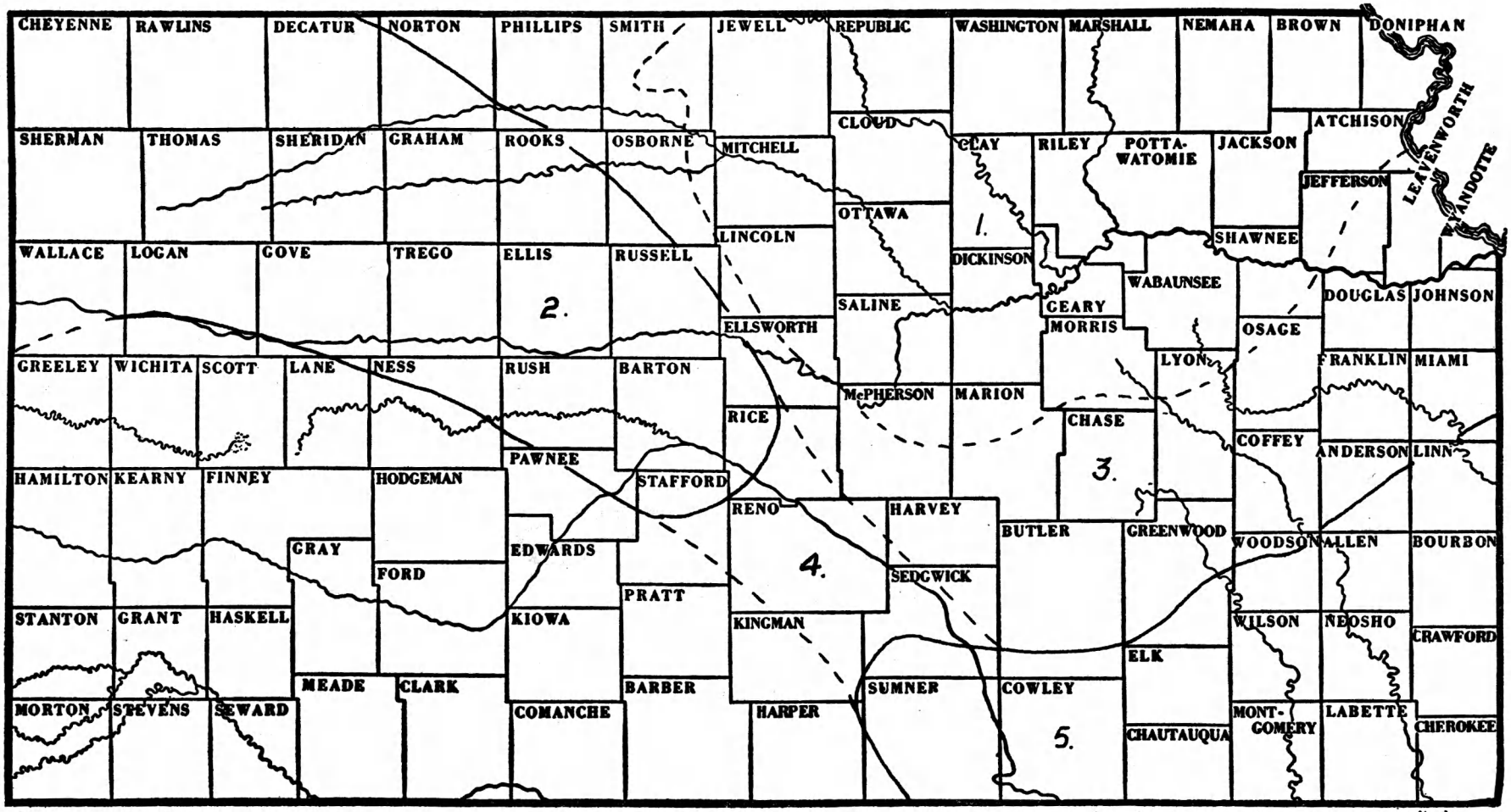


Fig. 5. Pre-Mississippian regional structures. (after Jewett, 1954)

1. North Kansas Basin
2. Ellis Arch
3. Ozark Monocline
4. Central Kansas Arch
5. Chautauqa Arch

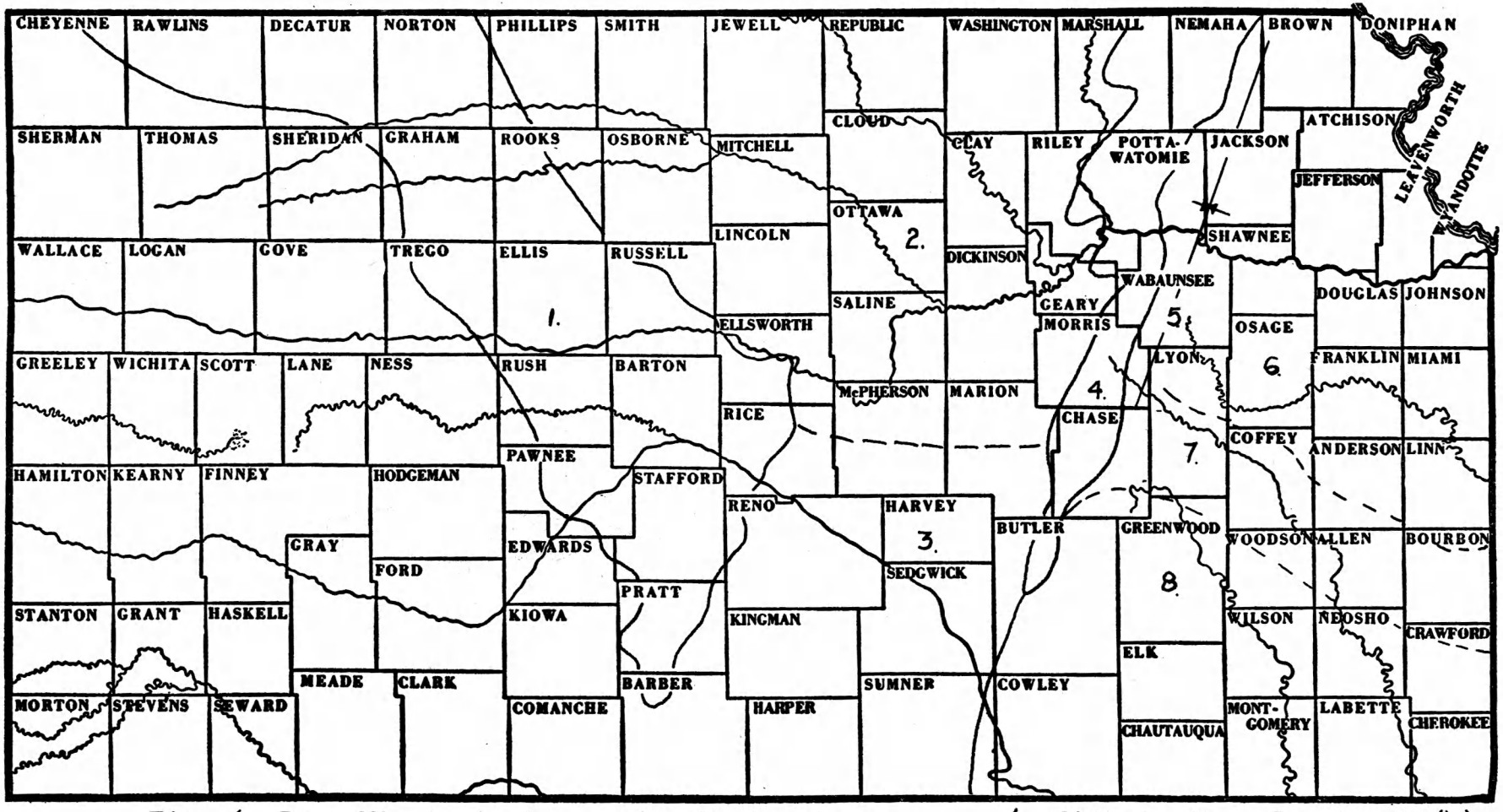


Fig. 6. Post-Mississippian regional structures. (modified after Jewett, 1954)

1. Central Kansas Arch
2. Salina Basin
3. Sedgwick Basin
4. Nemaha Anticline
5. Brownville Syncline
6. Forest City Basin
7. Bourbon Arch
8. Cherokee Basin

Figures 7 through 10, inclusive
in accompanying plate box.

PERMIAN
LOWER PERMIAN
WOLFCAMPIAN
CHASE
M.P.
LEON
SUMN.
WELLINGTON FORM.
NOLANS LS.
ODELL SH.
WINFIELD LS.
DOYLE SH.
BARNESTON LS.

(after Mudge et al, 1958)

CARTER OIL CO. NO. 1 HALE WHITE
C NW NW SEC. 17, T. 16S., R. 8 E.
0-3,218'

SYSTEM | SERIES | STAGE | GROUP | FORMATION | Gamma Ray Curve | Lithology | MEMBER | Neutron Curve

PERMIAN
LOWER PERMIAN
WOLFCAMPIAN
CHASE
COUNCIL GROVE
BARNESTON LS.
MATFIELD SH.
WREFORD LS.
SPEISER SH.
FUNSTON LS.
BLUE RAPIDS SH.
CROUSE LS.
EASLY CREEK SH.
BADER LS.
STEARNS SH.
BEATTIE LS.
ESKRIDGE SH.
GRENOLA LS.
ROCA SH.
RED EAGLE LS.
JOHNSON SH.
FORAKER LS.
ADMIRE
WABAUNSEE
HOWARD LS.
SEVERY SH.
NO SAMPLES
Cottonwood ls.
Neva ls.
500'
Happy Hollow ls.
1000'

PENNSYLVANIAN
UPPER PENNSYLVANIAN
VIRGILIAN
SHAWNEE
DOUGLAS
PEDEE
LANSING
KANSAS CITY
PLEASANTON
MARMATON
TOPEKA LS.
CALHOUN SH.
DEER CREEK LS.
TECUMSEH SH.
LECOMPTON LS.
KANWAKA SH.
OREAD LS.
LAWRENCE SH.
STRANGER FORM.
STANTON LS.
VILAS SH.
PLATTSBURG LS.
BONNER SPRINGS SH.
WYANDOTTE LS.
LANE SH.
IOLA LS.
CHANUTE SH.
DRUM LS.
CHERRYVALE SH.
DENNIS LS.
GALESBURG SH.
SWOPE LS.
LADORE SH.
HERTHA LS.
FORT SCOTT LS.
Heebner sh.
Amazonia ls.
Ireland ss.
1500'
Robbins sh.
Haskell ls.
Tonganoxie ss.
2000'
Little Osage sh.

PENNSYLVANIAN
MIDDLE PENNSYLVANIAN
DESMOINESIAN
CHEROKEE
MISSISSIPPIAN
DEV - MISS.
MISSISSIPPIAN L.S.
CHATTANOOGA SH.
2500'
Meisner ss.
3000'
SIL.-DEV.
ORDOVICIAN
MIDDLE ORDOVICIAN
UP. ORD.
HUNTON
SIMPSON
MAQUOKETA SH.
VIOLA LS.
PLATTEVILLE FORM.
ST. PETER SS.

LINCOLN OIL CO. NO. 1 BRECKBILL
NE SE SE SEC. 24, T. 16S., R. 5 E.
2,808' - 3,069'

ORDOVICIAN
CAMB.
LOWER ORDOVICIAN
UP. CAMB
ARBUCKLE
COTTER & JEFF CITY DOLO.
ROUBIDOUX FORM.
BONNETERRE DOLO.
LAMOTTE SS.
PRECAMBRIAN ROCKS
3000'

SCALE 1" = 40'

EXPLANATION

- Shale
- Sandy shale
- Calcareous shale
- Sandstone
- Shaly sandstone
- Calcareous sandstone
- Limestone
- Dolomite
- Sandy limestone
- Sandy dolomite
- Shaly limestone
- Shaly dolomite
- Cherty limestone
- Cherty dolomite
- Cherty, weathered, limestone
- Granite

Figure 7. Generalized stratigraphic sequence, Geary and Morris Counties, Kansas.

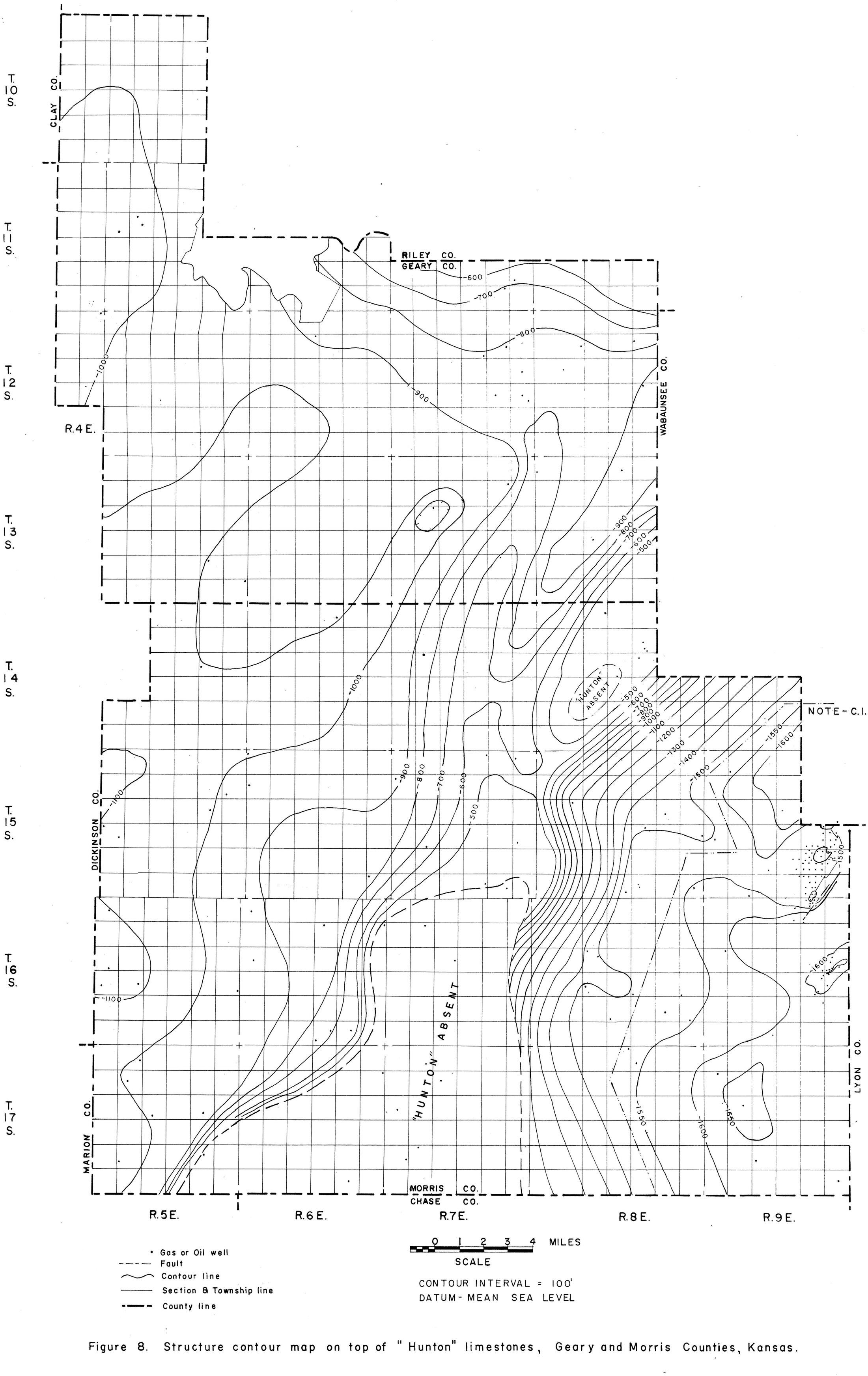


Figure 8. Structure contour map on top of "Hunton" limestones, Geary and Morris Counties, Kansas.

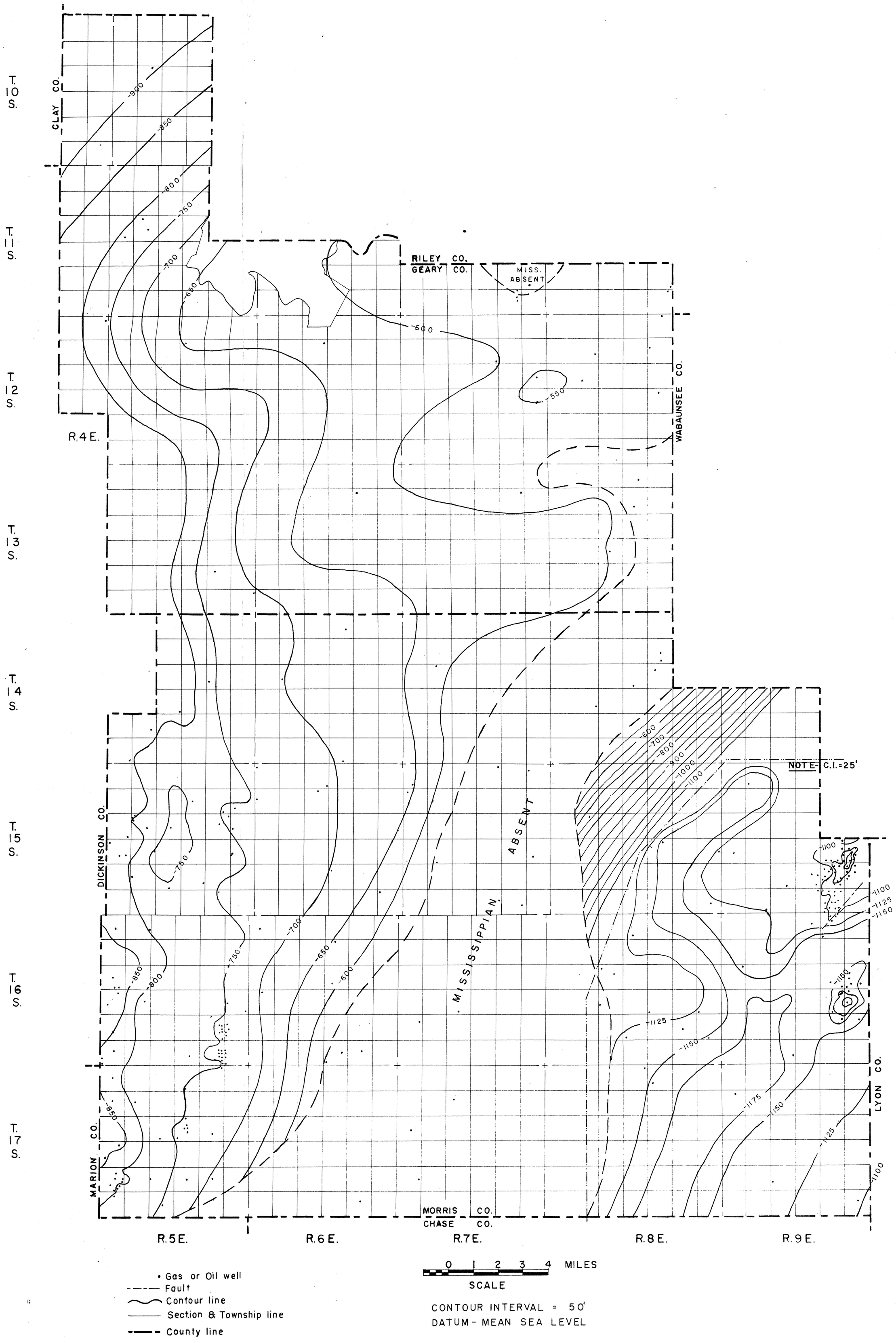
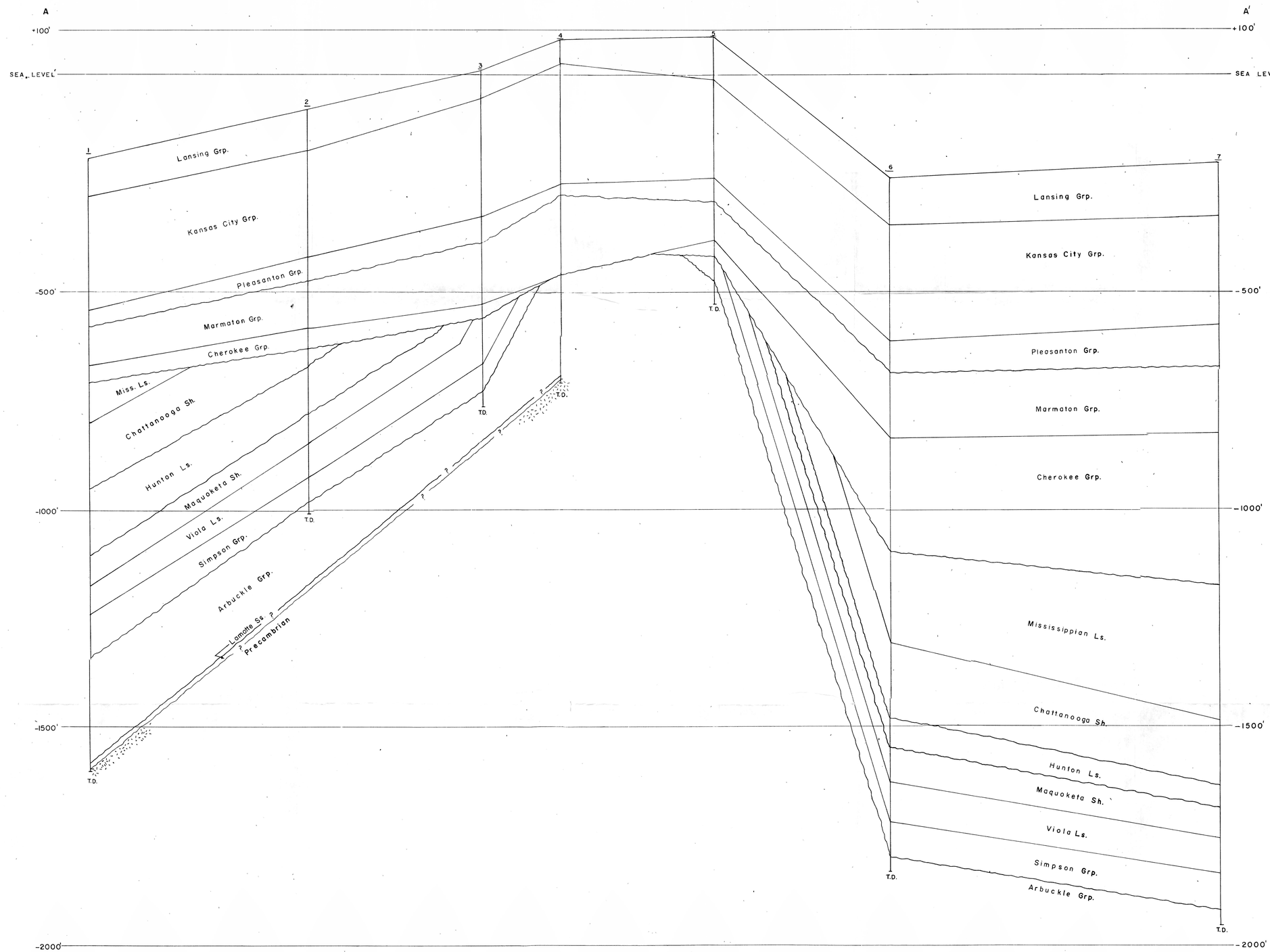
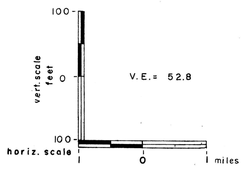


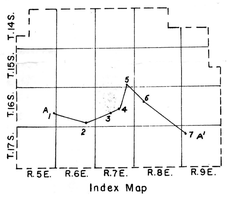
Figure 9. Structure contour map on top of Mississippian limestones, Geary and Morris Counties, Kansas.



No	Location	Company	Well Name
1	NE SE SE 24-16-5	Lincoln Oil	No. 1 Breckbill
2	SW SW NE 35-16-6	Adair Oil	No. 1 Lindquist
3	SE SE SE 21-16-7	Stanolind Oil and Gas	No. 1 Richardson
4	SE SE SE 15-16-7	Westgate Oil	No. 1 Orphans Home
5	SW NE SE 35-15-7	Anderson-Prichard Oil	No. 1 Lawrence
6	C NW NW 17-16-8	Carter Oil	No. 1 Hale White
7	C NW NE 7-17-9	Gruenerwald Oil	No. 1 Hylton

All data obtained from electric logs





Index Map

Figure 10. Stratigraphic cross section, Morris County, Kansas.

SUBSURFACE GEOLOGY OF GEARY AND MORRIS COUNTIES, KANSAS

by

JAY E. STERNIN

B. S., The City College of New York, 1959

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology and Geography

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1961

The purpose of the investigation is to analyze and describe the subsurface stratigraphic and structural conditions in Geary and Morris Counties, and to relate these findings to the accumulation of petroleum.

Structure contour maps, a stratigraphic cross section, and an electric log depicting a generalized stratigraphic column have been constructed. Other figures and diagrams have been included to clarify the findings presented. The available literature has been reviewed; electric logs, sample logs, and driller logs have been examined; and a microscopic examination of well cuttings was done.

The stratigraphic sequence in the area ranges from Precambrian to Quaternary. In the basins to the east and west of the Nemaha Anticline a normal stratigraphic sequence is present, and on the flanks and crest of the anticline, beveled Mississippian and progressively older rocks are overstepped by "Cherokee" rocks. Locally, "Cherokee" sediments are absent, and rocks of the Marmaton group overlie eroded Arbuckle rocks.

The area has been subjected to five periods of regional warping. The third period, which ranged from early Mississippian through Permian time, was the strongest and resulted in the creation of the Nemaha Anticline and the Forest City and Salina Basins during the post-Mississippian pre-"Cherokee" interval. Parts of these 3 major regional structures lie within the area of this investigation.

The area has been incompletely tested for the presence of petroleum. Wells drilled in Geary and Morris Counties average approximately 1 per 11 square miles and 4.5 square miles, respectively.

Petroleum accumulation in the known areas of present or former accumulation can be attributed primarily to structural traps.

Numerous possibilities for discovery of new petroleum reserves remain as yet untested within the area. It is believed that additional stratigraphic traps resulting from updip permeability and porosity "pinchouts" of beveled Mississippian and older rocks exist within the area, and that careful attention should be given to those areas where known reservoir rocks lie unconformably beneath Pennsylvanian sediments. Future exploration may conceivably extend the Alma Anticline southward, or discover other structures en echelon to it. Two broad, southwestward trending anticlines are present within the area, however, lack of control precluded the use of a contour interval small enough (i.e., 10 feet) to show any possible closure. A closed anticline is indicated in T. 15 S., R. 5 E. (fig. 9), and it is believed that 30 feet of closure would have been indicated had a smaller contour interval been used (i.e. 10 feet).